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**Development of the AFRL Aircrew
Performance and Protection Data Bank**

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**Air Force Research Laboratory
Human Effectiveness Directorate
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TABLE OF CONTENTS

PREFACE	v
SUMMARY	v
1. INTRODUCTION	1
1.1 Overview	1
1.2 Background of DCS Research	2
1.3 Background of BIODYN	3
2. ALTITUDE DECOMPRESSION SICKNESS RESEARCH DATABASE	6
2.1 History of the DCS Research Database	6
2.2 Description of Studies in the DSC Research Database.....	6
2.3 DCS Bibliographic Database	12
3. WEB APPLICATION DEVELOPMENT	13
3.1 Use of the Altitude Data Bank	13
3.2 Development Platform and Technology	14
3.3 DCS Parameter Search.....	15
3.4 Bibliographic Search.....	18
3.5 ADRAC Model and Web Toolkit	20
3.5.1 Introduction to ADRAC.....	20
3.5.2 ADRAC Web Toolkit	21
4. CONCLUSIONS.....	25
REFERENCES	26
APPENDIX A. Definitions of Data Fields in the DCS Research Database	27
APPENDIX B. Sample Printable Citation List from Bibliographic Search.....	29
APPENDIX C. Operational Risk Comparison Chart	30
APPENDIX D. DCS Database Data Used in the Development and Validation of ADRAC Model	31
APPENDIX E. Internet Explorer Settings for Using the ADRAC Slider Program.....	32

LIST OF FIGURES

Figure 1. Altitude C-Chamber for DCS Research	3
Figure 2. Collaborative Biomechanics Data Network - Home Page.....	4
Figure 3. Home Page of the Air Crew Protection and Performance Data Bank	13
Figure 4. Comprehensive Parameter Search with 23 Search Fields	16
Figure 5. DCS Parameter Query Search Result Presented in a Data Grid	18
Figure 6. Bibliographic Search	19
Figure 7. Display of Bibliographic Query Results.....	19
Figure 8. ADRAC Lab Program of Detailed DCS Onset Prediction.....	22
Figure 9. Sample DCS Onset Curves Produced by ADRAC Lab Program.....	23
Figure 10. Slider Program of ADRAC Web Toolkit	24

PREFACE

The report serves as the documentation for the web application development of the AFRL Aircrew Performance and Protection Data Bank. The work described in this report was a joint effort between the Biomechanics Branch at Wright-Patterson AFB, Ohio and the Aircrew Performance and Protection Branch at Brooks City-Base, Texas. Both branches are part of the Human Effectiveness Directorate of the Air Force Research Laboratory. Technical support for this effort was provided by the General Dynamics Advanced Information Systems (GDAIS) under contract FA8650-04-D-6472. Technical manager of the program was Mr. John R. Buhrman. Dr. Andrew Pilmanis was the Principal Investigator for the altitude research. Dr. James T. Webb of Wyle Laboratories supplied the original databases, and Ms. Elaine R. Slansky of GDAIS supplied the ADRAC web model in support of the Aircrew Performance and Protection Branch.

SUMMARY

This report summarizes work on the Aircrew Performance and Protection Data Bank. This data bank is also referred to as the Altitude Data Bank, and was a collaborative effort between the AFRL Biomechanics Branch at Wright-Patterson AFB and Air Crew Performance and Protection Branch at Brooks City-Base. The data bank consists of the altitude decompression sickness (DCS) research database, the DCS bibliographic database, and the Altitude Decompression Sickness Risk Assessment Computer (ADRAC) model, and represents over 17 years of AFRL research and experiments in high altitude decompression sickness areas. This developmental work brings web-based multi-parameter search and multi-database access capabilities to the DCS research data.

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1. INTRODUCTION

1.1 Overview

The Aircrew Performance and Protection Branch of the Air Force Research Laboratory (AFRL) at Brooks City-Base, Texas, has been conducting high altitude decompression (DCS) research in its altitude chambers for over two decades. The results of over 3,000 exposures with both male and female human volunteer subjects, were deposited into the AFRL DCS research database. From these test data, the Altitude Decompression Sickness Risk Assessment Computer (ADRAC) model was developed and validated for predicting DCS risk during altitude exposures. In addition, over 1,700 publications related to DCS research have been collected in the DCS bibliographic database. These data represent unique and valuable scientific resources that could only be developed through significant investments by the Air Force. In order to preserve the data and provide on-line access to Air Force and DoD customers as well as to the general scientific community, AFRL's Biomechanics Branch and the Aircrew Performance and Protection Branch collaborated to develop the Aircrew Performance and Protection Data Bank (Altitude Data Bank) and integrate it into the AFRL Collaborative Biomechanics Data Network (CBDN). The CBDN is a collection of large biomechanics databases with centralized online data search, visualization, extraction, and analysis capabilities. These technologies were originally developed for the Biodynamics Data Bank (BIODYN), which is developed and maintained by the AFRL's Biomechanics Branch and has a publicly accessible website on the Wright Patterson AFB public server.

The main tasks of the current project were:

1. Integrate DCS research database and DCS bibliographic database into the CBDN central server database.
2. Develop BIODYN style web search capabilities for the two DCS databases.
3. Integrate ADRAC model as a web toolkit for DCS risk prediction.
4. Extend BIODYN's user management and access control technology to the DCS data.

Microsoft SQL Server was used as the main database for storage of the DCS data. The database server is separate from the web server and is located behind the fire wall at Wright-Patterson AFB for increased security. To facilitate user access and data searches, a web application was developed using Microsoft .NET technology as the programming platform. .NET technology gives sophisticated server-side programming capability for accomplishing the tasks, especially for the development of a web version of the ADRAC model. The Microsoft .NET framework is the programming foundation for all current Microsoft software products.

Currently, the developmental work has been completed and the web application for the Altitude Data Bank has been functioning as part of the CBDN. It has the capability of

searching the DCS research exposure data through 23 test parameters and the DCS bibliographic data on author and title/keyword. It provides the ADRAC model in the format of either detailed DCS onset tables/curves or as a quick slide bar calculator. The ADRAC model has been used by various Air Force customers including Air Force Special Operation Command (AFSOC) at USAF bases around the world as well as NASA.

1.2 Background of DCS Research

Decompression sickness can occur when the human body is subjected to a large reduction in environmental pressure, such as ascent in the atmosphere, or decompression from compressed gas, diving, etc. Because the body is saturated with nitrogen that is dissolved in the tissues and fluids from breathing, a rapid and large enough reduction of environmental pressure against the tissue pressure of nitrogen can lead to the transition of nitrogen from the dissolved state into the gas state as gas emboli. The physical interactions of gas bubbles with tissues and fluids produce DCS symptoms. The resulting symptoms include pain, sensory deprivation, skin manifestations, and respiratory distress (Pilmanis, Petropoulos, Kannan, and Webb, 2004)

The focus of the DCS research conducted at the Aircrew Performance and Protection Branch was in the area of “altitude” DCS because it is more relevant to the Air Force. There are fundamental differences between DCS resulting from altitude exposure and from diving exposure (Pilmanis, 1995). Altitude DCS symptoms are usually mild and limited to joint pain since the breathing gas is high in oxygen, the time of decompression exposure to altitude is limited, and pre-oxygenation (pre-mission denitrogenation) is normally employed to reduce DCS risk (Webb, Pilmanis, & Krause, 1999). However, these characteristics may contribute to the reluctance of pilots to submit formal reports of DCS due to the fear of being grounded, even though the incidence of DCS during high altitude missions is actually quite high (Bendrick, Ainscough, & Pilmanis, 1996). Therefore, the experimental DCS research that simulates high altitude operational flight profiles becomes an important means to address potential operational DCS problems.

The main test facilities used for conducting the experimental research are a group of altitude chambers located at Brooks City Base, Texas. They range in size from 35 to 5,000 cu ft. with capabilities of temperature and humidity control, explosive decompression testing, and decompression sickness research. Figure 1 shows the C-Chamber that is a rectangular steel structure of 1,920 cu ft. The compartment of the chamber can accommodate up to 20 human subjects. The chamber compartment may be evacuated to simulate any desired altitude between ground level and 50,000 feet using two Nash vacuum pumps, or 100,000 feet using 5 Kinney vacuum pumps. These two systems are used independently with isolation valves. The chamber is structurally able to simulate altitudes up to 100,000 feet. The altitude may be controlled either manually or automatically, and the chamber can be kept at specific altitudes for a period of more than one year.

The physiological experimental measurements taken include EKG, oxygen saturation, and inspiratory demand. An Echo Imaging System with Robotic Arm is used for imaging intracardiac circulating gas emboli in human subjects. The majority of the experimental studies were directed towards development of objective techniques for determining DCS risk and preventive measures in a wide variety of current and future aerospace decompression situations. From 1983-2005, approximately 3,000 exposure records were obtained from 26 DCS studies conducted using these altitude chambers. There were more than 500 male and female human volunteer subjects that participated in these experiments. Two of the most significant applications of these experiments are the ADRAC model development and simulation of U-2 high altitude profiles, and high altitude parachute operations. All these data are now available through the Altitude Data Bank.



Figure 1. Altitude C-Chamber for DCS Research

1.3 Background of BIODYN

The Collaborative Biomechanics Data Network (CBDN), which includes the Biodynamics Data Bank (BIODYN), is a group of Web applications and databases developed and maintained by the AFRL's Biomechanics Branch at Wright-Patterson AFB. Its primary mission is to provide a data repository and offer both DoD and the public access to data related to anthropometry, biomechanics, and human performance. Currently, it contains the following components:

1. Air Force Biodynamics Data Bank (BIODYN)
2. Rocket Sled and Ejection Test Data Bank
3. Naval Biodynamics Laboratory (NBDL) Data Bank
4. Anthropometry Research Information System (ARIS)
5. Air Force Aircrew Performance and Protection (Altitude) Data Bank

6. Wind Tunnel Data Bank
7. Vibration Data Bank
8. Dynamic Environment Simulator (DES) (or Centrifuge) Publication Data Bank

The BIODYN and Altitude databases are free for public use but require user ID and password for access. Users can obtain access by submitting a one-time registration request on-line, and are normally granted immediate access and download privileges. The home page of CBDN (Figure 2) has internal links to each of the above databases, although currently only the BIDOYN and Altitude databases are available on-line to the public. Three of the databases are in the partial completion stage, including Vibration, Wind Tunnel, and Dynamic Environment Simulator (DES).

The largest of the five active databases, the Biodynamics Data Bank (BIODYN) was established in 1984 by a team of researchers at AFRL (Abrams, Kaleps, and Brinkley, 1988), known as the Armstrong Aerospace Medical Research Laboratory at the time. It has evolved from a main-frame command driven system into a dynamic Windows-based system with a web browser and full search capabilities (Buhrman, 1998; Cheng & Buhrman, 2000). The contents include data from over 10,000 impact acceleration tests conducted in-house at AFRL with both human subjects and instrumented manikins. The tests were conducted on man-rated impact test facilities capable of providing a wide range of acceleration pulses for simulation of both ejection and automotive impacts. The facilities include the Vertical Deceleration Tower (VDT), Vertical Accelerator (VA), Vertical Impact Device (VID), Horizontal Impulse Accelerator (HIA), and Horizontal Decelerator (HD). These tests have been a primary source of Biodynamic response data for engineers at AFRL as well as other research agencies and universities, and have led to improvements in the areas of ejection injury criteria, restraint system safety, and impact response modeling.

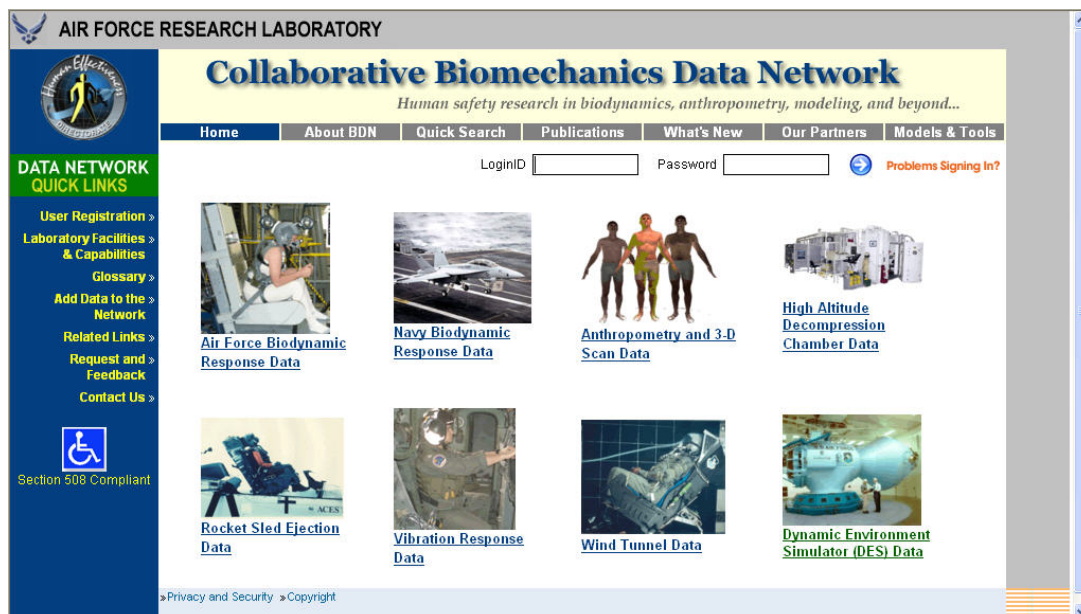


Figure 2. Collaborative Biomechanics Data Network - Home Page

BIODYN is the first component in this group of databases, and has the most comprehensive data collection including information on research studies, test data including multi-channel time histories, test parameters, sensor information, subject anthropometry, manikin measurements and drawings, literature of biomechanics research, test photos, and high-speed videos. It also contains web toolkits such as the Generator of Body Data (GEBOD) program (Gross, 1991; Cheng, Obergefell, and Rizer, 1994) for generating human and manikin data sets based on subject height and/or weight as well as percentile. Multiple search and visualization techniques were built into BIODYN. They consist of cross links among all types of data; searches through research topics, test data, and test parameters; web plotting of time histories; and video streaming of high-speed videos. These techniques were later applied in similar styles to other databases in the group.

The Rocket Sled and Ejection Database includes test data from nearly 1,000 rocket sled and ejection tests conducted at remote Air Force and Navy sites, including Holloman AFB in New Mexico. These tests were conducted with instrumented manikins at speeds and trajectories comparable to actual emergency aircraft ejections. Data from these tests have been used to establish the safety and reliability of ejection seats, restraint devices, and instrumentation systems.

The Naval Biodynamics Laboratory (NBDL) Data Bank is similar to BIODYN except the data were collected at the Naval Biodynamics Laboratory at New Orleans, which was closed in the 1990s. These data include information from over 4,000 human and manikin impact acceleration tests along with 287 time histories and the anthropometry measurements from 200 of the test subjects. All requests for test data from this database should be referred to the Naval Air Systems Command (NAVAIR), located at Patuxent River Naval Air Station in Maryland.

The Anthropometry Research Information System, ARIS, is the latest addition to the CBDN and is still under active development. The ARIS backend database contains the Civilian American and European Surface Anthropometry Resource data (CAESAR) (Robinette, *et al.*, 2002). CAESAR is the first large anthropometry survey that used 3-D full body laser scanning extensively in addition to traditional anthropometric measurements. It is comprised of over 4,000 subjects ages 18 to 65 from North America and Europe. The use of laser scans allows capture and analysis of individual shapes instead of just traditional summarized statistics. Therefore, ARIS will become a valuable resource for fitting and designing clothing and personal equipment, work stations, and digital human models. Eventually, ARIS will connect a group of anthropometry databases around the world through XML Web Services.

With each new addition of databases, the CBDN encompasses more diversified but inter-related data sources. The integration of various disparate scientific and technical data sets offers an excellent platform for data fusion and knowledge discovery in the field of biomechanics, anthropometry, physiology, human performance, and biometrics.

2. ALTITUDE DECOMPRESSION SICKNESS RESEARCH DATABASE

2.1 History of the DCS Research Database

The original DCS research database used for the web development of the Altitude Data Bank was provided by Dr. James T. Webb from the Wyle Laboratories at Brooks City-Base in Texas in support of the Air Crew Performance and Protection Branch. The database was created in the early 1980s to manage the large amount of data gathered from each subject exposure and provide a means of retrieving that data. It was originally located on a UNIVAC computer (System 2000 database created, in part, by Bill Nixon of the Biostatistics Division) at the Human Resources Division (HRL), then transferred to the VAX 11-70, and in 1998 was converted to a desktop PC using Microsoft Access 97. The conversion to MS Access allowed retrieval of information to become much easier and data entry to become more standardized. In the following years after this transition, some database tables were deleted or separated into other databases because they were not perceived to be of current or future research value to the Altitude Data Bank.

The MS Access database contains eight tables: Subject, Injury, Flight, Segment, Bubbles, Symptoms, Medication, and Study Design. Each subject could participate in many *Flights*, several of which could be described by one *Study Design*. Each exposure has a discrete number, the automatically-assigned Man-Flight-Number (MFN), which may be associated with many or few *Bubble* records and several or no *Symptom* records. Each MFN will also have several *Segments* describing the pressure changes and may have several breathing *Gases*. As time passes, each *Subject* may also acquire new *Injuries* and take different *Medications*. The relationships between these tables are defined and assigned to account for the temporal and pressure variables of each exposure and the resulting subject reactions, so as to allow retrieval of the correct information by the user commands.

In 2005, the DCS database was ported to MS SQL Server 2005, located at the AFRL Biomechanics Branch at Wright-Patterson AFB for the development of the Altitude Data Bank. During this migration process, some data that had potential privacy concerns were removed from the database. This allowed the public release of the database and its associated web application. In addition, most of the tables were combined into a single large table for easy web application development. Because SQL Server is designed to handle large quantities of data, this integration of tables had no adverse effects on query performance. Currently, the BIODYN team maintains the internal SQL Server database, and the 88th Communication Group at Wright Patterson AFB maintains the public SQL Server database.

2.2 Description of Studies in the DSC Research Database

The DCS studies are organized according to Institute Review Board (IRB) approved protocols. In the database, they are registered using their short protocol titles. The short

protocol titles were created and used in planning, scheduling, and most conversations about the protocols. The following paragraphs list short protocol titles (underlined) with their formal protocol titles (italic). In addition, brief introductions are provided for some studies.

100% Suit

Decompression Sickness (DCS) Protection Using a 100% Oxygen Pressure Suit Environment

The 100% Suit study was designed to provide a scientific basis for selection of the lowest pressure for extravehicular activity (EVA) pressure suits which will eliminate the hazards of DCS and severe bubbling (precordial Doppler bubble grades 3 and 4). Each subject was exposed one time so that a Probit analysis could establish a curve representing the population response to increased altitude of exposure without prebreathe. The altitudes of exposure were based on the 8.3 psia (pounds per square inch absolute) study pressure and reduced 0.5 psia in succession. The study was only designed to observe pressures down to 6.8 psia (19,800 ft) because it was believed that at least 50% DCS would be observed at that altitude based on observations of Venous Gas Emboli (VGE) and even a couple of cases of DCS during the 7.8 psia study.

35K

Decompression Sickness on Exposure to a Simulated Altitude of 35,000 Feet

This study was sponsored by USSOCOM and was designed to determine the effect of exposure to 35,000 ft on DCS incidence relative to 30,000 ft and provide input for development of the ADRAC model.

40K

The Effect of Exposure to 40,000 Feet on Altitude Decompression Sickness (DCS) Incidence

This study was sponsored by the US Navy SAILSS program and was designed to determine the effect of exposure to 40,000 ft on DCS incidence relative to 30,000 ft and 35,000 ft.

7.8 psia

Decompression Sickness Protection Using an 8 psi Suit Environment

8.3 psia

Decompression Sickness Protection Using an 8 psi Suit Environment

9.5 psia Validation

9.5 psia Bubble Threshold Validation

The study used 40% oxygen and 60% nitrogen breathing mixture.

Adynamia

The Effect of Adynamia on Altitude Decompression Sickness (DCS) Incidence

The Adynamia Study was sponsored by NASA to investigate the effects of simulated weightlessness on incidence and severity of decompression sickness as related to extravehicular activity from the Space Shuttle or International Space Station.

ARGOX

Staged Decompression with an Argon-Oxygen (ARGOX) Breathing Mixture to 3.5 psia

Ascent Rate

The Effect of Ascent Rate to 40,000 Feet on Decompression Sickness (DCS) Incidence

This study was sponsored by the US Navy SAILSS program and was designed to determine the effect of ascent rate on DCS incidence.

Break in Prebreathe

The Effect of an Air-breathing Break during Preoxygenation on Decompression Sickness Risk

The Break-In-Prebreathe study was supported by AFRL and was designed to determine if a break in prebreathe significantly degrades effectiveness of a 1-hour total prebreathe. Results could be applied to the U-2 program and NASA extravehicular activity.

BSI

Bends Screening Index

The BSI study was designed to develop an innocuous method of testing for bends susceptibility:

- a. Explore the bubble-bends relationship (of grade IV bubblers, what is the probability of developing clinical bends in a given individual at a specific altitude and exercise level?).

- b. Develop conditions for a screening test (what is the optimal altitude and exercise level that gives the best population spread of bends susceptibility to clearly separate “easy” from resistant “benders”?).
- c. Do the results of the susceptibility test apply equally well in classifying susceptibility at other levels of altitudes and exercise stress?

This study was sponsored by NASA and designed to determine the highest altitude at which individuals became symptom-free during multiple exposures at the same or successively lower altitudes if they developed DCS at the highest altitude exposed. This would determine an index of their susceptibility and a measure of how many exposures were necessary to make such a determination.

Bubble Threshold

Bubble Threshold Study

CO₂

Effect of Carbon Dioxide on Decompression Sickness

This study was sponsored by NASA and designed to determine if 3% CO₂ in the prebreathing gas would render the prebreathe more effective at preventing DCS.

The CO₂ study initially involved two 3-hour exposures at simulated altitudes up to 25,000 ft with a 1-hour prebreathe of either 100% oxygen or 97% oxygen and 3% carbon dioxide. Due to initial insufficient DCS incidence (8% ~ 10%), the exposures were lengthened to 6 hours. During the 6-hour exposure, 86% incidence occurred within 3 hours, compared to only 9% during the 3-hour exposures. Was the anticipation of 6 hours of exposure too much for the subjects?

DNT

Effect of Inflight Denitrogenation on Altitude DCS

The DNT study was designed to investigate the feasibility of in-flight denitrogenation (DNT) for use by U-2 pilots during emergency dispersal of aircraft when prebreathe at ground level would not be possible.

At the final altitude of 29,500 feet the subjects performed an exercise/rest/monitoring cycle designed to simulate the minimal exercise experienced by a pilot flying an aircraft and required about 100 Kcal·hr⁻¹. The exercise consisted of a 5-min period of rope pulling every 15 min throughout the exposure. The spring-loaded rope-pull device (MGI Mini Gym© Model 180) was marked at a peak resistance of 75.6 N (17 lbs). When the timing light was lit, the subject would pull the handgrip with both hands, from eye-height at arms' reach, to their lap, once every 5 sec, at a rate sufficient to cause the indicator to

superimpose on the peak resistance mark. The subject held the handgrip in his lap until the timing light went off (about 2 s), at which time the subject returned the handgrip to eye-height at arms' reach to repeat the cycle. The rope-pulling exercise followed a 5-min period of rest seated in a chair, and the rest was followed by a 5-min period of echo-imaging and joint flexion while reclined at the echo-imaging station.

EEP3

The Effect of Exercise-Enhanced Prebreathe on Decompression Sickness (DCS) Risk at 25,000 ft

This Exercise-Enhanced Prebreathe study was supported by AFRL and USSOCOM and provided information on the effectiveness of a decompression sickness prevention method for operational use during CV-22 or other special operations forces missions.

Effect of Exercise

Effect of Exercise on Altitude Decompression Sickness

An evolution from the Old ISO Study, this protocol used ambulatory rest with VGE monitoring during exposure to establish the highest altitude at which a subject would not develop DCS. The upper and first exposure altitude was set at 29,500 ft (to avoid the extra prebreathe requirement for inside observers at 30,000 ft vs. 29,500 ft). If the subject developed DCS during this first exposure, his (all male study) next exposure was at 27,500 ft, then 25,000 ft, then 22,500 ft until no DCS occurred. The exercise exposures were commenced at the highest and earliest (in sequence) altitude where, at ambulatory rest with VGE monitoring, the subject did not develop DCS.

MV

Decompression Sickness (DCS) Model Validation

The purpose of this study was to provide validation for a new altitude DCS risk assessment model developed at AFRL. The "heavy" exercise consisted of cycle ergometry (Monarch 818E) at approximately 30% VO₂peak (2 kp, 60 rpm) for 3 of each 10 min. Subjects were ambulatory and monitored for VGE during the 7 min of rest between each exercise period (3/10 X 30% = 9%). The average % of VO₂peak during the ergometry was between 10 and 15 % after accounting for basal metabolism, a very mild increase due to ambulation and VGE monitoring.

N₂O₂

The Effect of Breathing Gas Mixtures Containing Various Inert Gas Levels on Decompression Sickness (DCS) Risk

The Effect of Breathing Gas Mixtures study was supported by USSOCOM and provided information on the degree of decompression sickness risk during operational mission scenarios using several physiologic support and aircraft pressurization environments.

Old ISO Study

The Effect of Isometric and Isotonic Exercise on Altitude Decompression Sickness

This study was an initial effort to determine the effect of exercise mode on altitude DCS. However, the results indicated that, at 25,000 ft, insufficient DCS would be evoked to allow a comparison of exercise effects. Since no subject completed all the planned exposures, all were listed as “withdrawn” meaning they did not finish the protocol.

Oxygen Toxicity

Pulmonary Tolerance to 100% Oxygen at 9.5 psia

PE1

Effect of Prebreathe with 100% Oxygen while Exercising on Incidence of Decompression Sickness (DCS)

PE2

Preoxygenation with Exercise versus Rest: Effect on Incidence of Decompression Sickness (DCS)

Post-Exposure Exercise

Post-Exposure Exercise and Risk of DCS

The Post-Exposure Exercise Study was sponsored by USSOCOM and the results were of benefit in determining whether decompression sickness is a factor during insertion of Special Forces high altitude parachute operations.

PRK

Altitude Effects on Photorefractive Keratectomy (PRK) Eyes

This experiment was designed to cause hypoxia in the cornea of subjects and not to provoke or test DCS risk. Hence, no subjects developed DCS during the study. VGE data were not taken on the 35K exposures (N=80) since they only lasted a maximum of 30 minutes and other activities precluded observations.

Repeat

Effect of Repeat Exposures on Incidence of Decompression Sickness (DCS)

The Repeat study was sponsored by USSOCOM and the results were of benefit in determining whether decompression sickness is a factor during training of Special Forces where multiple high altitude parachute jumps are accomplished in one day.

ZPB

Decompression Sickness Protection below 25,000 Feet Using 100% Oxygen without Prebreathe

The Data Bank has a total of 3,443 tests in 26 studies. Each study may also be divided into multiple profiles. These profiles typically represent different configurations of test conditions, such as prebreathe time, mixture of nitrogen and oxygen amount, level of excise, and level of simulated altitude etc.

2.3 DCS Bibliographic Database

In addition to the DCS research database, the Altitude Data Bank also includes a DSC bibliographic database with 1,770 related literature citations spanning the last 100 years.

They constitute a concentration of information in this special research area, and are primarily citations of technical reports, journal publications, conference proceedings, and a few technical notes. Each citation is comprised of authors, title, publication source, publication date, and research laboratory etc. Some also provide full abstracts.

3. WEB APPLICATION DEVELOPMENT

3.1 Use of the Altitude Data Bank

Users can navigate to various parts of the Altitude Data Bank by logging in at the CBDN home page (Figure 2) and then clicking on the link to “High Altitude Decompression Chamber Data,” which will then display the Altitude Data Bank home page (Figure 3).

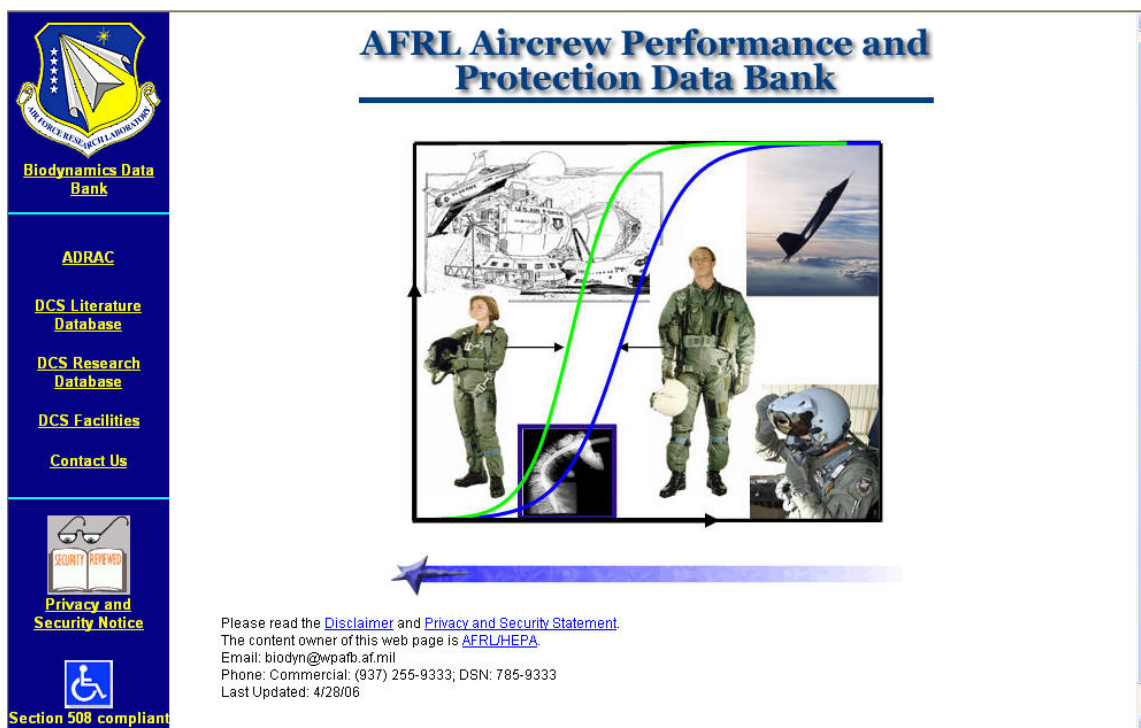


Figure 3. Home Page of the Air Crew Protection and Performance Data Bank

There are several items on the left blue menu bar with links to the various components of the Data Bank. Among these links:

ADRAC – Altitude Decompression Sickness Risk Assessment Computer Model. ADRAC is the main web toolkit of the Altitude Data Bank. It provides quick online assessment of DCS risk based on altitude, prebreathe time, exposure time, and exercise level. It calculates and presents the results in two formats:

Lab Program – Detailed DCS onset table/curves – Percentage of DCS incidence at 10 minute exposure time intervals, up to 240 minutes.

Slider Program – A single percentage value of DCS incidence, changing dynamically when the user moves the input sliders

DCS Literature Database – Bibliographic database with capability of searching by authors, titles, and/or keywords

DCS Research Database – DCS study data with capability of parameter search on 23 data fields. This is the main search tool of the Data Bank.

DCS Facilities – Introduction to DCS research equipment.

Because the Altitude Data Bank has been integrated with other parts of BIODYN, once logged in, the user could also access other databases depending on his/her granted right. New users can apply for accessing BIODYN by submitting a registration. The registration form is located under the link “User Registration” on the BIODYN home page (Figure 2). User applications are subject to review and approval.

3.2 Development Platform and Technology

BIODYN was developed using Microsoft Active Server Page (ASP) technology. ASP allows development of dynamic web contents from backend databases using ActiveX Data Objects (ADO). Microsoft eventually phased out this software development technology and released the new .NET Framework with associated server and client development tools such as ASP.NET and ADO.NET. The .NET Framework fundamentally changes the entire development environment and aims at next generation software products. It addresses some major drawbacks in the old ASP and ADO technology, such as lack of object-oriented design, messy spaghetti code, slow performance of script, lack of scalability, memory leak, and lack of adequate web services support etc.

The development of the Altitude Data Bank was done in Microsoft Visual Studio, which offers this new software environment. The main technologies used were ASP.NET for Web development, ADO.NET for data connectivity, and VB.NET as the programming language. All three technologies are based upon and run on top of the .NET Framework 1.1. The .NET Framework has two main components: the common language runtime (CLR) and the .NET Framework class library. The .NET Framework class library is a collection of reusable types that tightly integrate with the common language runtime. The class library is object-oriented namespace hierarchy that covers a wide range of software development tasks. The three technologies, ASP.NET, ADO.NET, and VB.NET used in the Data Bank development, are part of this hierarchy. Therefore, they can work seamlessly together. The CLR is the foundation of the entire Framework. It manages memory, thread execution, code execution, type enforcement, code safety and verification, compilation, and other system services. Compared with old Windows runtime, it manages code directly at the execution time. This brings several significant advantages:

1. High level of security – Each managed component will have a different degree of trust. One benefit of this is to allow feature-rich web component executing on the user's computer but not allowing access to the user's personal data.
2. Strict type-and-code-verification infrastructure – Common type system (CTS) ensures that all managed code is typed and self-describing. One benefit of CTS is to allow mixed language programming. The choice of programming language is no longer an important factor for software development.
3. Safe and efficient execution – Automatic code memory management. One benefit of this is the object reference management and memory release. It prevents the two most common application errors, memory leak and invalid memory reference.
4. Enhanced performance – Just-in-time (JIT) compiling enables the managed code to be compiled and run in the native machine language of the system on which it is executing. One benefit of this is complete elimination of the slow interpreted code of ASP and VB.

ASP.NET is the primary tool used to write the web pages for the Altitude Data Bank. In ASP.NET, a web page typically consists of a group of web control classes with event handling and functional logics. The ASP.NET web controls are sever-side controls which have much richer functionalities than those of traditional HTML controls. This makes the development of complex web GUI features possible, such as the multi-page navigation data grid that was used to present DCS database query results. The ASP.NET also introduces new user authentication and encryption techniques. These security techniques were implemented in the Altitude Data Bank for storage of user information and handling of user access. The database connection and search are usually done through ADO.NET. ADO.NET was designed to work in the disconnected mode of web databases, such as the Altitude Data Bank.

The programming language chosen to be used in the project was VB.NET. Unlike the old Visual Basic which at most is a component-based structured language, the new VB.NET is a full functional object-oriented language, i.e., it provides capabilities of abstraction, encapsulation, inheritance, and polymorphism. Compared to the other object-oriented language, it is very close to JAVA in language features, including advanced ones such as multithreading and reflection. On the other hand, VB.NET does not have the features that are more error-prone, such as pointer type used in C++. It also has advanced exception handling capability. Overall, the use of .NET Framework and Visual Studio offers the Altitude Data Bank the latest software technology, enhanced performance, and high productivity.

3.3 DCS Parameter Search

The parameter search pages are comprised of two parts, parameter selection and query result presentation. The parameter selection page lists DCS data fields for users to select

and set search parameters. It has 23 search fields (Figure 4). Related fields are grouped into the same row. These selected parameters are used to construct the search condition clauses for the database query.

Research Database Parameter Search

Note: This is an **AND** search. The more boxes you check, the smaller the result set. Refer to [Database Introduction](#) for detailed definition of each search field.

ShortTitle

To select multiple items in the following list boxes, press and hold [Ctrl] key when making selections

ShortTitle-Profile	Subject Number	Gender	
<input type="text" value="100% Suit-A"/> <input type="text" value="100% Suit-B"/> <input type="text" value="100% Suit-C"/> <input type="text" value="100% Suit-D"/>	<input type="text" value="16"/> <input type="text" value="17"/> <input type="text" value="18"/> <input type="text" value="19"/>	<input type="text" value="Female"/> <input type="text" value="Male"/>	
Prebreathe Activity	Prebreathe Gas	Prebreathe Duration (min)	
<input type="text" value="Blank"/> <input type="text" value="10 min Dual Cycle Ergometry, Non-Ambulatory Rest"/> <input type="text" value="15 min Dual Cycle Ergometry, Non-Ambulatory Rest"/> <input type="text" value="Ambulatory Rest"/>	<input type="text" value="Blank"/> <input type="text" value="100% O2"/> <input type="text" value="2.8%N2/4.2%Ar/93%O2"/> <input type="text" value="3% CO2 - 97% O2"/>	<input type="text" value="0"/> <input type="text" value="15"/> <input type="text" value="25"/> <input type="text" value="30"/>	
Stage Activity	Stage Gas	Stage Duration (min)	Stage Altitude (ft)
<input type="text" value="Blank"/> <input type="text" value="Ambulatory Rest with VGE Monitoring"/> <input type="text" value="Non-Ambulatory Rest with VGE Monitoring"/>	<input type="text" value="Blank"/> <input type="text" value="100% O2"/> <input type="text" value="38% O2 - 62% Ar"/> <input type="text" value="50% N2; 50% O2"/>	<input type="text" value="Blank"/> <input type="text" value="60"/> <input type="text" value="120"/> <input type="text" value="180"/>	<input type="text" value="Blank"/> <input type="text" value="0"/> <input type="text" value="8000"/> <input type="text" value="12000"/>
Exposure Activity	Exposure Gas	Exposure Duration (min)	Exposure Altitude (ft)
<input type="text" value="Ambulatory EVA Exercises"/> <input type="text" value="Ambulatory Rest"/> <input type="text" value="BSI Exercises"/> <input type="text" value="Cycle Ergometry at 30% VO2peak"/>	<input type="text" value="100% O2"/> <input type="text" value="100%O2"/> <input type="text" value="2.8%N2/4.2%Ar/93%O2"/> <input type="text" value="40% O2 - 60% N2"/>	<input type="text" value="30"/> <input type="text" value="90"/> <input type="text" value="120"/> <input type="text" value="180"/>	<input type="text" value="9000"/> <input type="text" value="10000"/> <input type="text" value="10250"/> <input type="text" value="11500"/>
Post-Exposure Activity			
<input type="text" value="Blank"/> <input type="text" value="Ambulatory Rest with VGE Monitoring"/> <input type="text" value="Dual Cycle Ergometer at 50% VO2peak"/> <input type="text" value="Referred to HBM - DCS that did not resolve on descent or serious DCS symptom(s)"/>			
Symptom Description	Symptom Location	Temporal Sense	Symptom Severity
<input type="text" value="Blank"/> <input type="text" value="Abnormal reflex"/> <input type="text" value="Additional information in 'Comments'"/> <input type="text" value="Blurred vision"/>	<input type="text" value="Blank"/> <input type="text" value="Abdomen"/> <input type="text" value="Ankle"/> <input type="text" value="Back"/>	<input type="text" value="Blank"/> <input type="text" value="Constant"/> <input type="text" value="Transient"/> <input type="text" value="Transient, with movement only"/>	<input type="text" value="Blank"/> <input type="text" value="1"/> <input type="text" value="2"/> <input type="text" value="3"/>

Values entered in the following range boxes will replace any selections made in their corresponding list boxes

Find Records between Exposure Altitude (ft) and

☒ AND ☐ OR between Exposure Duration (min) and

☒ AND ☐ OR between Prebreathe Duration (min) and

Figure 4. Comprehensive Parameter Search with 23 Search Fields

Depending on the type of the selection field, it is modeled using one of the following ASP.NET Web controls:

List box – Model multi-selection fields

Dropdown list box – Model single selection fields, inherited from list box

Text box – Model numerical range inputs

These controls are server-side controls. When the user clicks on and makes a selection change in an individual web control, by default the page will be posted back to the server and the control's event handling method will be executed by the server. This allows the web page to perform input validation. Input validation was implemented for the text input boxes on this page as well as the user registration page. The server-side event handling also makes forming of complex database queries and mathematical operations possible because it bypasses the limitation of client-side Java script and is able to tap into the full capability of .NET Framework's class library.

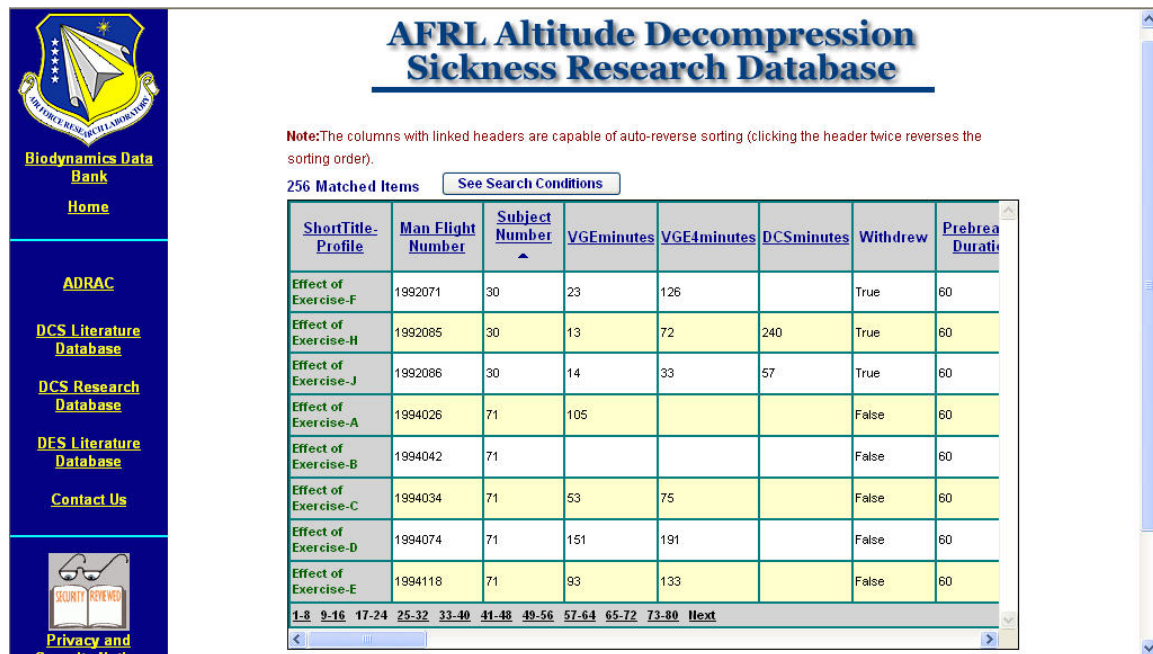
Most of the fields are *AND*ed together when forming the query except for a few numerical range inputs which allow AND or OR operation. Therefore, the more fields that are selected, the smaller the result set will be.

Because there is no lookup table storing parameter values, each web control's selection items are populated at run time through a dynamically formed distinct value "SELECT" query on the actual experimental data. Instead of doing each selection box individually, a WebControls ListBox array was built to complete the populating of all the selection boxes through a loop.

To make correct searches on the DCS research database, users should understand the meaning of each selected item in the different parameter fields. These items are usually abbreviations of particular experiment setups, procedures, and subject activities, etc. Items appearing in different fields may also be related to each other. A detailed document is attached to the web page under the link "Database Introduction" for user reference. After selections are made, pressing the "See Data" button will post the page back to the server. A query is built on-the-fly based on the user's selections and the results are presented in a data grid. Appendix A lists the definition for each of the data fields in the query result data grid.

The reporting of the DCS parameter search results was implemented using a data grid (Figure 5) which binds to a backend DataView object of ADO.NET. DataView object has built-in capabilities for filtering, searching, paging, and sorting. These capabilities were used directly in building the multi-page navigation and column sorting for the DCS data grid. Figure 5 shows the query results of the "Effect of Excise" study. It is a dataset consisting of 256 records, with each record having 39 data fields/columns. Therefore, it is a fairly large dataset. The pagination of the data grid displays 8 records per page. The page navigation links are listed at the bottom of the grid. The current page in Figure 5 displays records from record Nos.17 to 24. In addition, the display is sorted by "Subject

Number” in an ascending order as indicated by the arrow in the column title. Clicking again at the column title will reverse the order and the arrow. Compared to the traditional HTML tables used in the previous BIODYN applications, these features represent a more user-friendly way to report large datasets.



AFRL Altitude Decompression Sickness Research Database

Note: The columns with linked headers are capable of auto-reverse sorting (clicking the header twice reverses the sorting order).

256 Matched Items [See Search Conditions](#)

ShortTitle-Profile	Man Flight Number	Subject Number	VGEminutes	VGE4minutes	DCSminutes	Withdrew	Prebreath Duration
Effect of Exercise-F	1992071	30	23	126		True	60
Effect of Exercise-H	1992085	30	13	72	240	True	60
Effect of Exercise-J	1992086	30	14	33	57	True	60
Effect of Exercise-A	1994026	71	105			False	60
Effect of Exercise-B	1994042	71				False	60
Effect of Exercise-C	1994034	71	53	75		False	60
Effect of Exercise-D	1994074	71	151	191		False	60
Effect of Exercise-E	1994118	71	93	133		False	60

1-8 9-16 17-24 25-32 33-40 41-48 49-56 57-64 65-72 73-80 Next

Figure 5. DCS Parameter Query Search Result Presented in a Data Grid

Another important performance enhancing technique used in the DCS data reporting is the caching of the query results. The results are cached at the server after the initial page load so subsequent refreshing of the page can obtain the data faster from the cached copy than by re-querying the database. However, due to the space and memory limit, the cached copy may be removed by other higher priority datasets and operations if it isn't accessed recently. Therefore, a check mechanism and refilling function were programmed to reload the dataset from the database if the cached copy was removed by the system.

3.4 Bibliographic Search

The 1,770 bibliographic citations in the Altitude Data Bank represent a single location for the large number of high altitude DCS related publications, many of which are from AFRL due to its long time research work in this area. These publications are often sought by other researchers such as those involved in private space exploration and NASA projects. In order to facilitate access to these publications, a bibliographic search was built against the high altitude DCS bibliographic database (Figure 6). It allows users to search by authors, titles, and/or keywords. The query results are presented in a multi-

page data grid (Figure 7). Furthermore, users can see full bibliographic information including abstracts by clicking the “More” link buttons in the “Full Biblio” field.

AFRL Decompression Sickness Literature Database

DCS Literature Search

Check one or both checkboxes to activate the corresponding input fields

- ☒ **Search on Authors** - Enter author's name. Separate the authors by commas. For example: Jones, Smith brings up all articles by Jones and Smith.

Webb, Pilmanis

- ☐ **Search on Titles or Keywords** - Enter words/phrases appearing in the titles or keywords. Separate each of them by comma. For example, EVA, Canada brings up all articles with both words in either the title or the keywords.

See Files

Clear All Boxes

Figure 6. Bibliographic Search

AFRL Decompression Sickness Literature Database

85 Matched Items

Check All Boxes

Un-Check All Boxes

Produce Citations

Print Citation	Authors	Title	Year	Source	Full Biblio
<input checked="" type="checkbox"/>	Balldin UI, Pilmanis AA, Webb JT	Hypobaric decompression sickness and simulated weightlessness	2001	Aviat Space Environ Med	More...
<input type="checkbox"/>	Balldin UI, Pilmanis AA, Webb JT	Hypobaric decompression sickness and adynmaia	2001	Bioastronautics Investigators' Workshop (NASA). Galveston, TX. January, 2001	More...
<input checked="" type="checkbox"/>	Balldin UI, Pilmanis AA, Webb JT	Pulmonary decompression sickness ("chokes") symptoms and circulating gas emboli during simulated altitude exposure	2002	Résumés des Présentations Orales 49ÈME Congrès International de Médecine Aéronautique et Spatiale Genève (Suisse).	More...
<input type="checkbox"/>	Balldin UI, Pilmanis AA, Webb JT	The effect of simulated weightlessness on hypobaric decompression sickness	2002	Aviat Space Environ Med	More...
<input type="checkbox"/>	Balldin UI, Pilmanis AA, Webb JT	Pulmonary decompression sickness at altitude: Early symptoms and circulating gas emboli	2002	Aviat Space Environ Med	More...
1-5 6-10 11-15 16-20 21-25 26-30 31-35 36-40 41-45 46-50 Next					

Full Bibliography

Keywords: chokes review etiology DCS medium high symptom

Type: Peer-Reviewed

Laboratory: AFRL

Full Date:

Volume/Pages: 73 / 996-9

Contract#:

Section:

IRB#:

Index:

Info:

DTIC#:

STINFO#: AFRL-HE-BR-JA-2001-0024

Abstract:

Introduction. Pulmonary altitude decompression sickness (DCS) is a rare condition. 'Chokes', characterized by the triad of substernal pain, cough and dyspnea, are considered to be associated with severe accumulation of gas bubbles in the

Figure 7. Display of Bibliographic Query Results

Once the user finds items of interest, he/she can add them to a printable list of citations by checking the corresponding check boxes in the leftmost column “Print Citation”. The citation list is produced by clicking the “Produce Citations” button at the top of the grid. Appendix B shows a sample list.

3.5 ADRAC Model and Web Toolkit

3.5.1 Introduction to ADRAC

Operations in non-pressurized aircraft capable of long duration high-altitude flight involve a risk of decompression sickness (DCS). For example, the Air Force Special Operations Command (AFSOC)’s future CV-22 Osprey is capable of high altitude long duration flights. One of the primary limitations to the AFSOC mission will be DCS. Appendix C presents the comparison graphic of DCS incidence percentage in the research environment versus operational scenarios. In light of deployments of the V-22 to combat zones by the Marine Corps, mission planners, flight surgeons, and pilots need a rapid and easy way of calculating the risk of DCS.

The purpose of the AFRL ADRAC (Altitude Decompression Sickness Risk Assessment Computer) model is to provide the capability of predicting the incidence of DCS symptoms when exposed to a specific altitude exposure profile. The program is designed primarily for predictive applications such as mission planning, design of aircraft pressurization systems, design of space suits, design of DCS countermeasures, research and other pre-altitude exposure applications. In addition, real-time applications are possible.

ADRAC predictions are based on four input parameters: altitude, time at altitude, pre-oxygenation time, and level of physical activity. ADRAC cannot predict the DCS incidence in a single individual; rather it predicts DCS for a population of people that reflect the USAF flying personnel with respect to gender, age, physical fitness, height, weight, and general health. The basic method of this program involves a combination of two models:

1. A mathematical bubble growth model for calculating DCS risk below 22,500 feet, which uses a finite difference method to solve for bubble radius as a function of time.
2. A statistical model for calculating DCS risk above 22,500 feet. The statistical altitude model is based on the results of human altitude exposure research in the DCS research database.

ADRAC was developed at the AFRL Aircrew Performance and Protection Branch at Brooks City-Base with Dr. Andrew Pilmanis as the Principal Investigator. The bubble growth model was developed by Lambros Petropoulos of Wyle Laboratories, and the statistical model by Dr. Nandini Kannan of the University of Texas at San Antonio. The

DCS Database information used for the model development was provided by Dr. James Webb of Wyle Laboratories.

The original ADRAC program was a stand-alone console program written in FORTRAN. Later a JAVA based graphical user interface (GUI) was added by a third party contractor, NCrist Software Solutions, Inc., Houston, Texas. In 2004, the stand-alone version was modified and developed into a Web toolkit with a GUI similar to the JAVA version, by Elaine Slansky of General Dynamics Corp., using ASP.NET and VB.NET. Subsequently, it was integrated into the Data Bank by the Biomechanics Branch in 2005.

During the development of the ADRAC Web pages, a special logic was added for altitude values in the range of 22,500 to 25,000 feet, since the original model under-predicts DCS by 5–15% for altitudes within this range. This logic first computes a straight line equation using the two endpoint DSC values at 22,500 and 25,000 feet, and user inputs for prebreathe time and exercise level. The value for time at altitude varies from 0 to 240 minutes in increments of 10 minutes. The user input for altitude is then plugged into the straight line equations and the results are used for the DCS prediction instead of the original model.

ADRAC is based on more than 20 years of hypobaric chamber studies using human subjects at AFRL. Appendix D lists all the studies and associated profiles used as the basis for the development and validation of ADRAC model. These data are stored in the DCS research database. During the model validation, the predictions of the model were close to the experimental data for all scenarios and within 5% of the actual values. A complete and detailed description of the model development and validation can be found in the reference (Pilmanis, Petropoulos, Kannan, & Webb, 2004).

3.5.2 ADRAC Web Toolkit

DCS risk predictions can be obtained by using either the Web Toolkit, called the “Lab Program” with detailed DCS onset table and corresponding curves, or the less complex “Slider Program” which has a single DCS risk value that instantaneously responds to user inputs. Users can select either program from the ADRAC home page. The ADRAC home page is under the link “ADRAC” on the left menu bar of the Data Bank’s home page (Figure 3).

Lab Program

The Lab Program (Figure 8) allows the user to compute up to five scenarios of DCS onset tables and curves. The three inputs for the ADRAC calculations are:

Altitude (feet): 18,000 – 40,000 feet

Prebreathe Time (minutes): 0 – 240 minutes

Exercise Level: Rest, Mild, Heavy

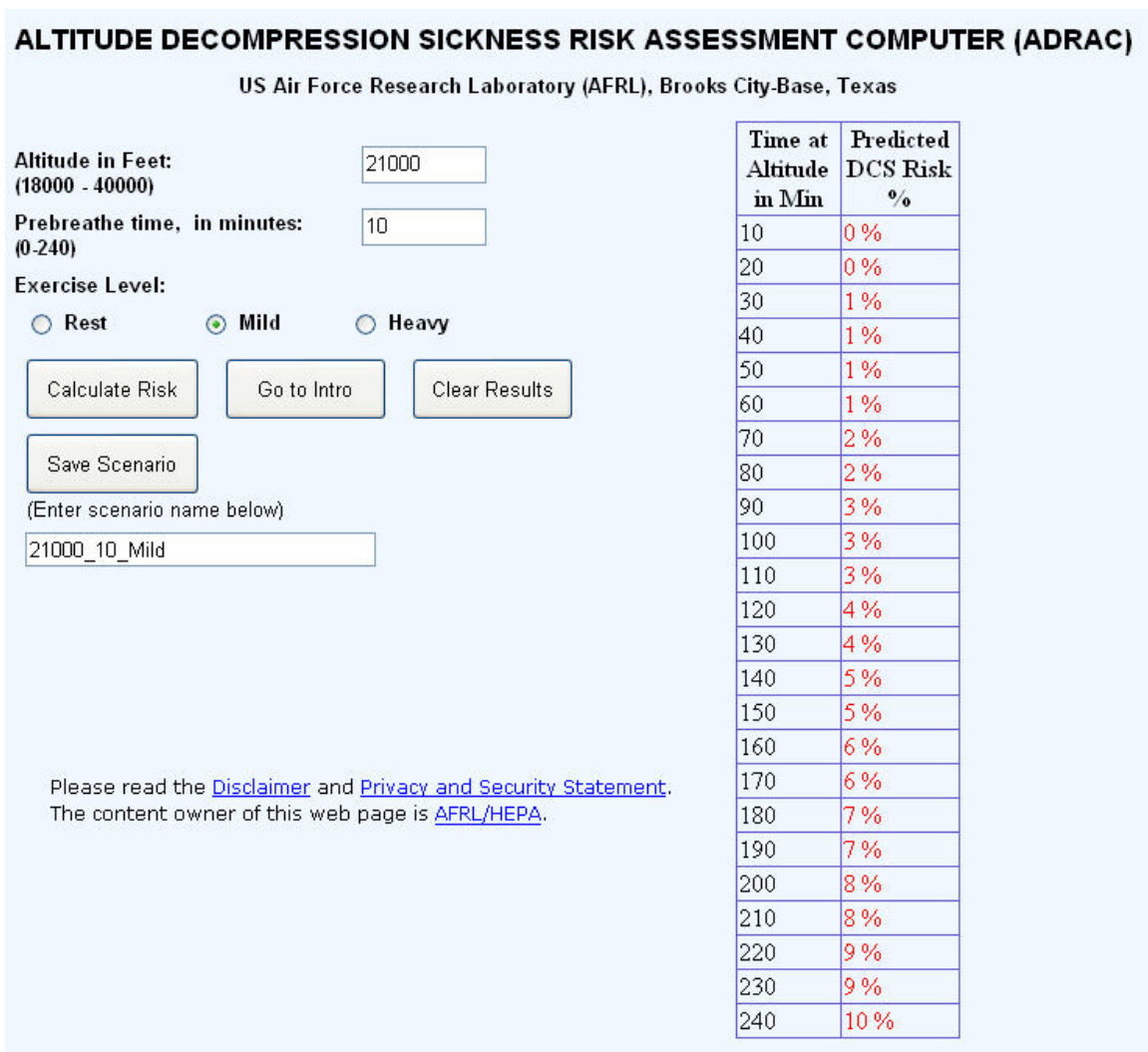


Figure 8. ADRAC Lab Program of Detailed DCS Onset Prediction

Pressing the “Calculate Risk” button will produce the DCS onset table displayed in 10 minute exposure time intervals. The risk value is the predicted percentage of cumulative DCS incidence. It should be noted that the ADRAC DCS risk predictions do not reflect reported operational DCS incidence for the simple reason that the majority of operational DCS cases are not reported. Rather, the predictions reflect the research results of exposures in AFRL altitude chambers. To see the predictions in graphic form, press the GRAPH button and then multiple (up to 5) scenarios will be plotted on the same graph (Figure 9). The plotting routine uses a third party web control software package, NPlot (<http://www.nplot.com/>). It is a free charting library for .NET Frameworks. In addition, the table can be saved into a comma delimited Excel spreadsheet by pressing the “Save Scenarios” button.

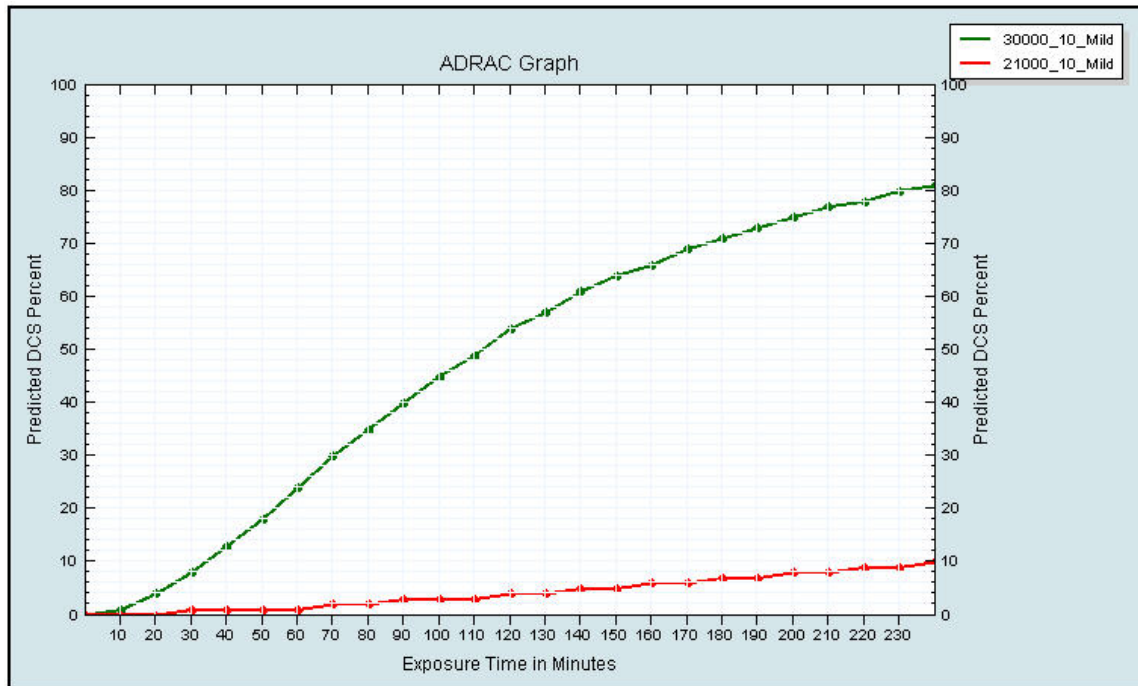


Figure 9. Sample DCS Onset Curves Produced by ADRAC Lab Program

Slider Program

The Slider Program allows faster DCS risk predictions. Simply move the sliders and the “Probability of DCS” will immediately change (Figure 10). In addition to the three input parameters used in the Lab Program, the exposure time (0 – 240 minutes) becomes another input value instead of the independent axis of onset curve. Three input text boxes were also added to the right of the slider bars to allow the user to enter exact numbers.

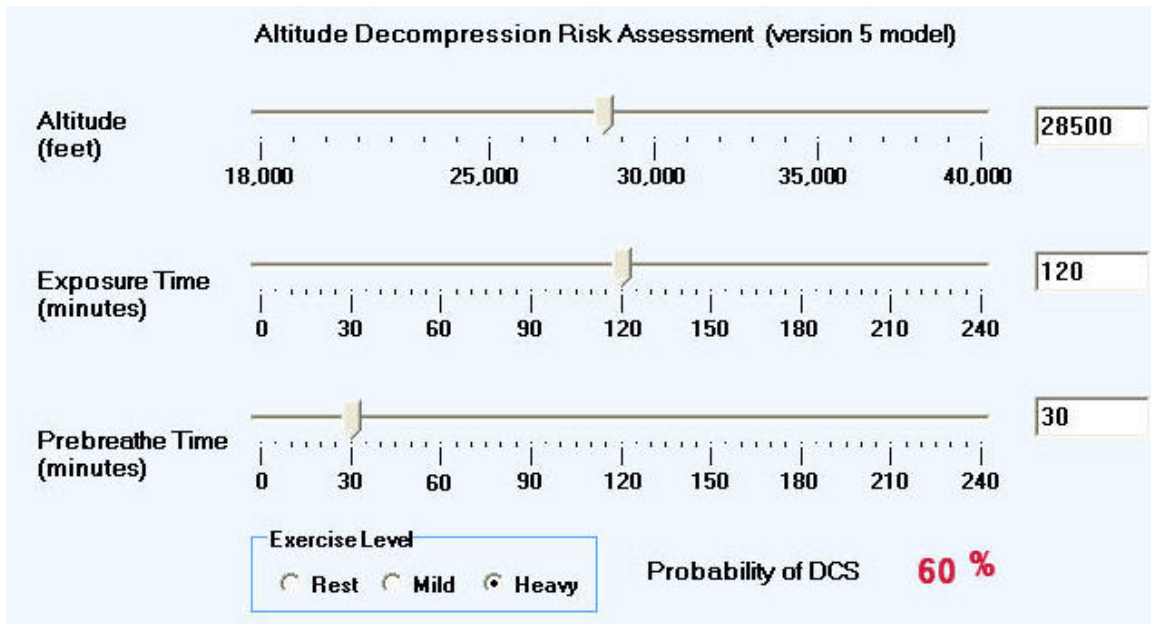


Figure 10. Slider Program of ADRAC Web Toolkit

The intuitive slider interface is preferred by some operational personnel due to its instant response and simple design. However, due to the stateless nature of the web application, a server-side web control would not be able to update quickly enough to follow the continuous movement of the sliders by the client. Therefore there is no slider web control available in the ASP.NET web control library. To realize this feature, a client-side custom control was built using Windows slider control from the VB.NET Form control library. The VB.NET Form control library is designed and used for Windows or mobile device GUI applications. The custom slider control built in this way functions like a JAVA applet. It requires the client to download the control automatically from the server when accessing the web page the first time. Then the control will install itself on the client computer and work as a local Windows component. However, this requirement creates problems with both the server and client. Currently, Air Force regulation prevents deployment of downloadable active components from its public web sites. Therefore, the Slider Program was not deployed to the public site, but does work through the Air Force intranet which requires a Common Access Card (CAC) for accessing the site. In addition, the user needs to configure their computer's internet setting according to the instructions in Appendix E in order to use the slider control. With continuous introduction of new Web technologies such as the recent AJAX (Asynchronous JAVA Script and XML) for interactive Web applications, the BIODYN team will investigate new ways to address this problem.

4. CONCLUSIONS

Through the cooperation of AFRL's Biomechanics Branch and Air Crew Performance and Protection Branch, a new web database application, the AFRL Air Crew Performance and Protection (Altitude) Data Bank, has been developed. The Altitude Data Bank consists of the DCS research database, the DCS bibliographic database, and the ADRAC model. It represents over 17 years of AFRL research and experiments in high altitude decompression sickness, and is a unique resource in this special physiology area. This developmental work brings web-based multi-parameter search and multi-database access capabilities to the DCS research data. A web toolkit for DCS risk prediction based on the combined Bubble Growth model and statistical model of hypobaric chamber simulations was integrated into the Data Bank. It offers a quick and readily accessible online DCS risk assessment tool for flight mission planners, operators, pilots, and commanders.

The Altitude Data Bank applies the latest database and web technologies and is capable of quickly delivering targeted data to customers in a user-friendly manner. It has been used remotely by customers such as AFSOC and NASA and is now an integral part of the AFRL Collaborative Biomechanics Data Network (CBDN). New data will be added into the CBDN in the future and new knowledge will be discovered through in-depth data mining of its various data sources. It is envisioned that the CBDN will be the center of data management and analysis for biomechanics, altitude physiology, and anthropometry research in DoD, as it becomes an invaluable tool for use by military operational personnel as well as civilian engineers and researchers.

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APPENDIX A. Definitions of Data Fields in the DCS Research Database

ShortTitle-Profile: Protocol/Study short title and decompression simulation profile

Man Flight Number: An auto-number generated when a new subject-exposure is entered into the database

Subject Number: Index number of human test subjects

VGEminutes: Time at which VGE (Venous Gas Emboli) is detected (minutes)

VGE4minutes: Time at which Grade 4 (highest VGE score) is detected (minutes)

DCSminutes: Time at which DCS incidence is detected (minutes)

Withdraw: Yes = subject didn't complete the test. No = subject completed the test

Prebreathe Duration: Duration of prebreathe of oxygen (minutes)

Prebreathe Activity: Subject activity routine during the prebreathe

Prebreathe Gas: Prebreathe gas mixture

Stage Altitude: Altitude of staging (feet)

Stage Duration: Time duration at the stage altitude (minutes)

Stage Gas: Gas mixture at the stage altitude

Stage Activity: Subject activity routine at the stage altitude

Exposure Altitude: DCS exposure altitude (feet)

Exposure Duration: Time duration at the DCS exposure altitude (minutes)

Exposure Activity: Subject activity routine at the DCS exposure altitude

Exposure Activity Level: Workload of subject activity routine (1 = rest, 2 = mild, 3 = heavy)

Exposure Gas: Gas mixture at the DCS exposure altitude

Post-Exposure Activity: Subject activity routine after DCS exposure

Gender: Gender of the test subject

Pre-Flight Weight: Subject weight before the test

Height: Subject height

BMI: Subject Body Mass Index

Body Fat: Subject body fat index

VO2max: Maximum VO2 consumption during the test (l/min)

Race: Race of the test subject

Age: Age of the test subject

MaxVGEGrade: Maximum VEG grade registered for the subject during the test. VGE score is a semi-quantitative 5-point score describing the amount of VGE in a heart cycle:

Grade 0 = no bubble signals

Grade 1 = occasional bubble signals

Grade 2 = frequent bubble signals

Grade 3 = many bubble signals, but they do not obscure the heart sounds

Grade 4 = numerous bubble signals that obscure the heart sounds

OnSet: Clock time of each observed DCS symptom (minutes)

Region: General body region (side(s) and anterior/posterior) where each observed DCS symptom occurs

Description: Description of each observed DCS symptom

Location: Segmental location of each observed DCS symptom

Temporal Sense: Temporal sense of each observed DCS symptom

Severity: Severity of the joint pain DCS symptom on a 1-10 scale with 1 being barely noticeable and 10 being the worst pain the subject can imagine

Resolved: Time at which the DCS symptom is resolved after the treatment (minutes)

Pressure of Disappearance: Pressure of the treatment at which the DCS symptom disappears (mm Hg)

Treatment: Name of the treatment procedure

Treatment Results: Whether symptom resolves before or after treatment(s)

APPENDIX B. Sample Printable Citation List from Bibliographic Search

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Pilmanis AA, Webb JT, Balldin UI. The impact of high levels of nitrogen in the breathing gas while at altitude on the risk of decompression sickness (DCS). *Aviat Space Environ Med* 2002;73:314.

Webb JT, Fischer MD, Heaps CL, Pilmanis AA. Exercise with prebreathe appears to increase protection from decompression sickness. *Seventh Annual Workshop on Space Operations, Applications, and Research (SOAR'93) NASA Conference Publication 3240* 1994;II:497-500.

Webb JT, Fischer MD, Wiegman J, Pilmanis AA. prebreathe enhancement with dual-cycle ergometry may increase decompression sickness protection. *Aviat Space Environ Med* 1993;64:420.

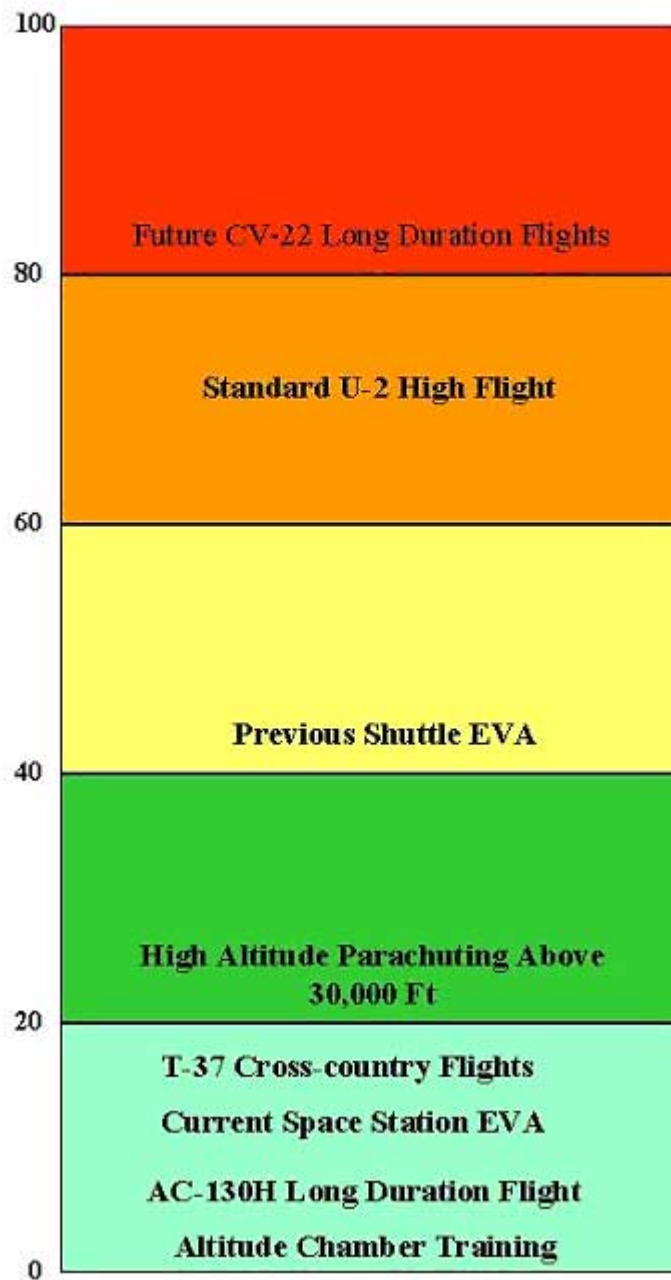
Webb JT, Kannan N, Pilmanis AA. Gender not a factor for altitude decompression sickness risk. *AFRL-HE-BR-TR-2002-0212* 2002:14pp.

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Webb JT, Pilmanis AA. Hypobaric decompression prebreathe requirements and breathing environments. *Sixth Annual Workshop on Space Operations, Applications, and Research (SOAR'92) NASA Conference Publication 3187* 1993;II:544.

APPENDIX C. Operational Risk Comparison Chart

DCS Symptom Incidence (%) in Research Subjects Exposed to Altitude Profiles Similar to These Operational Scenarios



**APPENDIX D. DCS Database Data Used in the Development and Validation of
ADRAC Model**

Profile #	Study Title-Profile	Complete Exposure #
1	100% Suit-A	10
2	100% Suit-B	10
3	100% Suit-C	10
4	100% Suit-D	10
5	100% Suit-E	10
6	100% Suit-F	10
7	35K-A	37
8	35K-B	30
9	35K-C	36
10	35K-D	31
11	BSI-A	15
12	BSI-B	37
13	CO2-A	38
14	CO2-C	25
15	DNT-A	39
16	DNT-B	18
17	DNT-C	32
18	Effect of Exercise-A	46
19	MV-A	31
20	MV-B	31
21	MV-C	30
22	MV-D	30
23	MV-E	31
24	Oxygen Toxicity-A&B	42
25	PE1-B	28
26	PE2-A	32
27	PE2-B	32
28	PE2-D	31
29	PE2-E	32
30	Post-Exposure Exercise-A	18
31	Post-Exposure Exercise-B	19
32	Post-Exposure Exercise-C	5
33	Repeat-A	35
34	ZPB-A	20
35	ZPB-B	20
36	ZPB-C	20
37	ZPB-D	10
38	ZPB-E	20
39	ZPB-F	22
40	ZPB-G	20
41	ZPB-H	9
	Total	1012

APPENDIX E. Internet Explorer Settings for Using the ADRAC Slider Program

Verify the installation of Microsoft .NET Framework v 2.0 – You can check this through Windows Control Panel’s “Add or Remove Program” window. If not installed, it can be downloaded from the following link:

<http://www.microsoft.com/downloads/details.aspx?familyid=9655156b-356b-4a2c-857c-e62f50ae9a55&displaylang=en>

In order to run the program properly, you should be using Internet Explorer (IE) version 6.

Additionally, settings will need to be changed in the Internet Zone. To change the settings in IE, go to the menu item and select Tools/Internet Options/Security Tab.

Select Internet/Custom Level and set everything to PROMPT.

Enable File Download.

Click the OK button to close the Security Settings window; then click OK again on the Internet Options window and it will close.

Be aware that this change will affect your access to other pages on the Internet, not just this web site.

Alternately, you can add this site to the Trusted Sites Zone and make the changes there instead.

Contact your workgroup manager if you need further assistance.